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FORECASTING QUANTITY OF DYESTUFFS AND AUXILIARY CHEMICALS DISCHARGED INTO GEORGIA STREAMS BY THE TEXTILE INDUSTRY

A THESIS

Presented to

The Faculty of the Graduate Division

by

Larry George Arnold

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FORECASTING QUANTITY OF DYESTUFFS AND AUXILIARY CHEMICALS DISCHARGED INTO GEORGIA STREAMS BY THE TEXTILE INDUSTRY

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

SUMMARY

Waste disposal and control is rapidly becoming one of the largest problems facing the textile industry. In particular, disposal of colored liquid waste is of utmost importance. This study was undertaken to evaluate color in Georgia streams as a result of textile wet-processing waste.

This thesis reports the quantity and concentration of the major textile wet-processing chemicals in effluents discharged into Georgia streams as waste.

Predictions are based on data obtained from questionnaires and consultations held with administrative and technical mill personnel in the Coosa River Basin of northwest Georgia where the textile industry is heavily concentrated.

The forecast indicates significantly heavy concentrations of dyestuffs and auxiliary chemicals in the waste waters from textile wet-processing operations and accordingly permits computation of chemicals present in streams for any water flow rate.

CHAPTER I

INTRODUCTION

The Textile Industry is the largest and oldest industry in Georgia. It is also the third largest industrial user of water as seen in Figure 1 and Table 1. Only the pulp and paper industry and the chemical industry use more water. Water has always been of utmost importance to the textile industry, the dyeing and finishing segments alone account for millions of gallons daily. Within the state, the textile industry in the northwest corner has, in the past fifteen years, shown a growth which is unequalled by the industry in any other geographic area. Because of the concentration of the industry in this section, it was selected for use as a model for a study forecasting the quantity of dyestuffs and auxiliary chemicals discharged into Georgia streams by the Textile Industry.

Any study of water use and waste control is much more effective if it can be isolated into a certain region. The Coosa River Basin in northwest Georgia was selected as a particular area for this study. This well-defined basin includes all or part of fourteen counties. Within the boundaries of the basin there is a total manufacturing employment of 44,134 (1). This figure includes only those people employed exclusively for manufacturing. Employment by textile companies, i.e., companies involved in any way with the manufacture of textiles is 27,181 (2), representing 61.6 percent of the total manufacturing employment in the basin. The preceding figures indicate one of the reasons

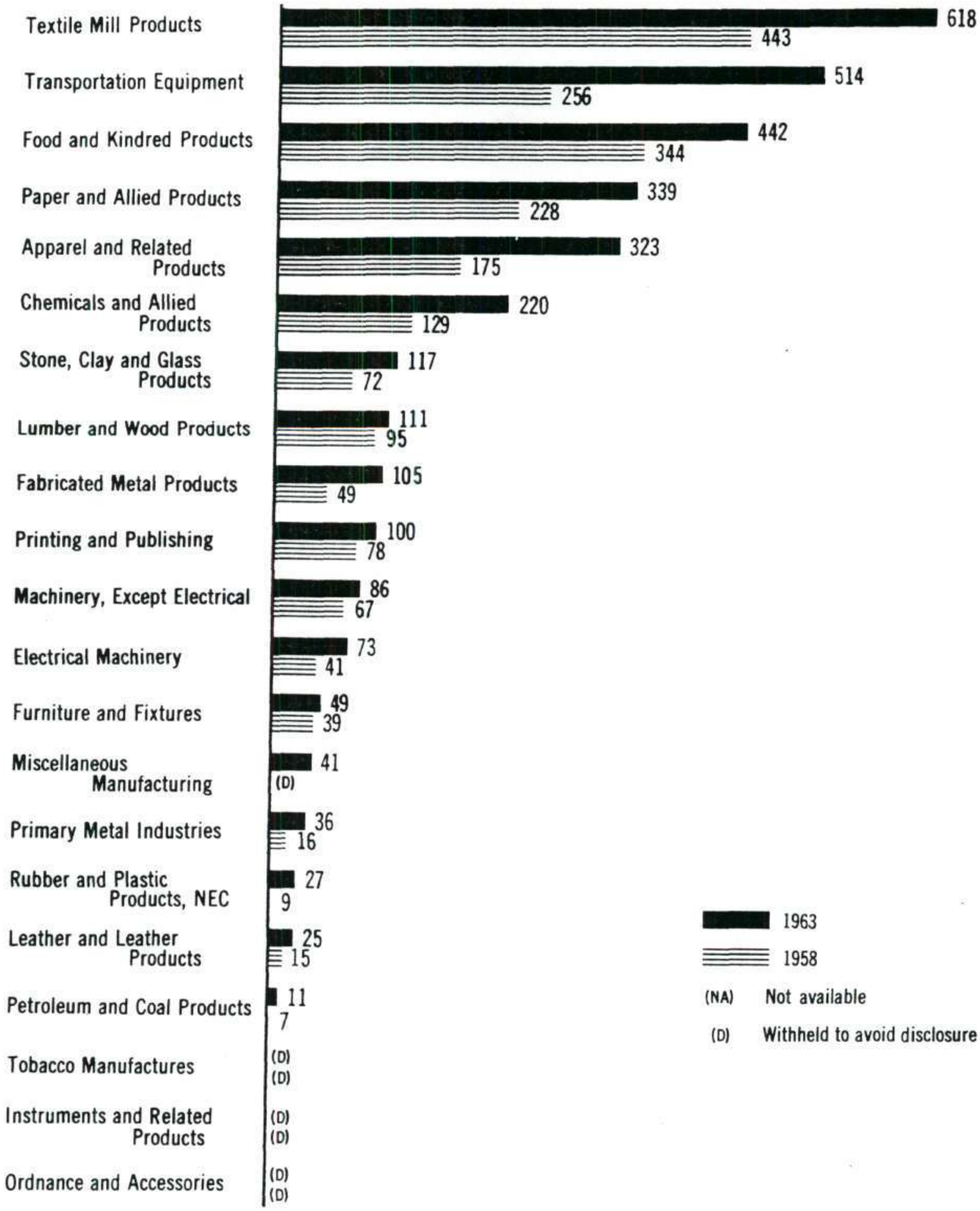

Figure 1. Value Added by Manufacture by Industry Group
(in millions of dollars)
U.S. Department of Commerce, Bureau of the Census

Table 1. Water Intake by Source, Gross Water Used, 1964, for Georgia by Industry

Industry	Value of Shipments $1,000	Water Intake by Source: Total	Fresh Water: Total	Fresh Water: From Public Water Systems	From Company Systems: Surface	From Company Systems: Ground	Brackish Water	Gross Water Used[1]
Georgia Total	3,569	228	184	26	59	98	44	655
Textile Mill Products	929	18	18	7	9	2	-	30
Food Products	604	11	10	4	4	3	(2)	13
Paper, Allied Products	475	163	126	9	44	74	37	525
Chemicals, Allied Products	210	29	23	3	2	18	6	55
Stone, Clay, Glass Products	80	3	3	(2)	1	1	-	10
Transportation Equipment	1,075	2	2	2	-	-	-	13

[1] all units billions of gallons except value of shipments.

Source: Bureau of the Census, Census of Manufactures.

for the selection of the Coosa River Basin as the model for this study.

Much research has been done in the field of water pollution by the textile industry. Most of the work done is referenced in a literature survey recently completed under the direction of Hyden (3). This survey made it clear that earlier similar studies were devoted primarily to the natural fiber segment of the textile industry and many are unrelated to the waste control problems which exist with synthetic and man-made fibers. It became apparent that more information was needed for a better description of that part of the textile industry which is involved primarily with these synthetic and man-made fibers. One project recently completed at Georgia Tech, showed that color downstream from dye-processing textile plants is a problem of increasing concern (4). The growing problem and the ensuing concern invited careful study, which formulated the present project.

The current project is being developed in two parts, a study of streams in the Coosa River Basin with particular respect to color and a statistical forecast of that portion of textile mill effluent that, under normal conditions, could be found in Georgia streams, this second portion being the format for this thesis.

The results of data obtained from textile mills in the Coosa River Basin provide the foundation for this thesis and a model for other basins in the state. The forecasted chemical predictions of this research should, in the future, correlate with the stream study previously mentioned.

Statement of the Problem

Color build-up in streams is a result of waste liquids from dyeing and finishing processes being directly discharged into streams and entering into streams indirectly through waste treatment plants. Color is often not susceptible to removal through high rate industrial waste treatment methods. The color may be a direct product of discharged dyestuffs or it may be the result of an interaction of colorless dye intermediates from one plant with intermediates or finishing agents from the same or other plants or with natural organic waste in the stream. The problem has been greatly complicated in recent years by the fact that new classes of dyes and chemical auxiliaries for dyeing and finishing processes are continuously being introduced as required by technologic innovations and new chemical types of fibers.

More precise knowledge of the characteristics of chemicals and dyes used in textile plants of different kinds is required in order to better define the problem. Knowledge of rates of color build-up is also required, as is the distribution in time of the quantities and structure of the chemicals in the effluent.

Chemicals, dyestuffs, and the associated processes primarily responsible for the color problem must be identified and evaluated. With this knowledge, it is possible that alternative dyes, chemicals or processes may be developed which would be more responsive to waste-treatment technology. Furthermore, improvements in process technology might be developed, resulting in a reduction in quantity of offensive chemicals discharged. For example, decreasing the ratio of chemicals discharged to chemicals adsorbed could result in a significant economic and stream quality improvement. A long-range objective is to obtain the cooperation of the textile industry in working toward a better appreciation of the significance and magnitude of, and a solution for the problem of preserving the aesthetic value and economic utility of our water resources for the benefit of future generations.

CHAPTER II

METHOD OF ATTACK

The method used to forecast the quantity of dyes and chemical auxiliaries discharged into Georgia streams by the textile industry was developed in two parts. The first part was the sending of questionnaires to selected mills and dye houses in the Coosa River Basin.

Obtaining information and data through the use of questionnaires always requires much work, especially if the returns desired are to be divulgent of a great deal of information. The questionnaires which were developed for this data-gathering were designed so that they could be quickly and easily completed without unnecessary problems such as the form in which to present the data. As the copies of the questionnaires in Appendix A show, care was taken to give the person filling out the questions enough choices as to how much detail the respondent cared to give. A choice was given as to whether the information was given on a daily or weekly or even monthly or yearly basis. An attempt was made also to give the respondent a choice of answers on questions such as source of water and fate of waste water discharged. Revisions were made when it was found that detergents, wetting agents, and other chemicals were extremely difficult to separate in mill records. This was found to be due to the extremely great amount of overlapping which takes place among textile auxiliaries of this nature. It was also found to be very difficult to identify some of these compounds since some results were shown as proprietary names and some simply as generic names without specific reference to chemical nature. Identification of these chemicals will be dealt with in more detail in Chapter III, Discussion of Results.

As mentioned above, the questionnaires were sent to selected companies and various points were considered before a company was selected as a good candidate to receive a questionnaire. The most important points were the size and the location of the dyeing and finishing operation. It was felt that a very small (1,000 pounds or less processed per month) operation which was located on a very large river or in a heavily populated area would not have the significance of a large operation on a small stream in a somewhat sparsely populated area. The size of the operation compared with all other similar operations was no more important than the size relative to the stream receiving discharged waste water from the operation.

Another very important point considered in selecting mills for data was the treatment or non-treatment of waste water after it left the mill. Observations made on streams containing the effluent of both industrial and domestic waste which had received treatment indicated that analyses, particularly with respect to color, would have been extremely difficult because of the mixing of various colors and chemicals in streams containing treated waste. For example, a stream containing treated industrial and domestic waste was found to remain a reasonably constant dull green color which was somewhat nondescript, while a stream containing untreated domestic and industrial waste could vary distinctly in color over a period of ten to fifteen minutes (5). This led to the conclusion that a study of streams carrying untreated waste could correlate with data obtained from mills whose effluent eventually made its way to the stream. Chemicals could be identified somewhat more readily with particular respect to their possible source.

The second step in the forecast of dyes and chemicals is an analysis of the data found in the returned questionnaires. It has long been recognized that any research problem is merely a case of obtaining raw data from a particular source and working with the data long enough until it is in a form which can be meaningfully correlated. The same case was true in this instance, since the data were being returned in various forms which were convenient to the management of the mills, it was necessary to reduce those data to a common basis. The most effective basis was found to be the total poundage of water and chemicals per pound of fiber processed in the operation. For example, a good guide to the amount of water used by various operations is the pounds of water necessary to produce one pound of product. Converting all the data from the form given to a common basis was a matter of first putting it on a weekly basis and then comparing the amounts of each chemical necessary to process one pound of product. When this was completed a total figure was given of the pounds of all chemicals, dyes, and water used to process one pound. This figure is easily convertible to a parts per million or milligrams per liter basis which is more feasible when correlation with stream conditions is attempted.

The cover letter which accompanied each questionnaire is found in Appendix A and it will be noted that all information supplied will be kept confidential. It was felt that this was the most satisfactory method for treatment of such data. Instead of showing the results of individual mills an attempt is made, based on the total production figures for the type of textile industry involved, to show a breakdown of how much of each type of chemical including dyes, acids, bases, salts, detergents and other chemicals is being eventually discharged as waste into streams. The figures shown will be based on the questionnaires, i.e., a constant will be obtained which will produce the amount of each type of chemical used throughout the industry. The major segment of the textile industry in the Coosa River Basin is the Tufted Textile industry and the figures given will be primarily for this industry since this is being set up as a model for other basins.

After obtaining the figures on the quantity of dyes and other chemicals to be found in the streams, predictions were made as to the fate of specific chemicals. These predictions, while not possible on a quantitative basis, were based on known chemical reactions and on reactions which were believed to take place but had not been shown before in any research literature due to their nature. The reactions between acids and bases are simply a formation of salt. The nature of the salt, whether acidic or basic depends entirely upon the components making it up. For example, the reaction of a strong base such as caustic soda (NaOH) and a strong acid such as hydrochloric (HCl) yields a neutral salt, sodium chloride (NaCl). Waste waters containing equal amounts of these two chemicals will show no extreme change in concentration of hydrogen ion (pH) as long as the system remains balanced. Another example is the reaction of the salt of a strong base and a weak acid, soda ash (Na_2CO_3) with a weak acid, acetic acid (CH_3COOH) which forms a basic salt, sodium acetate ($CH_3COO^-Na^+$), with the evolution of carbon dioxide. Similarly, a strong acid and a weak base react to form an acidic salt. It will, therefore, not be possible to predict the pH of waste waters from a mill other than predominantly acidic or basic or neutral. Carbon dioxide produced in biological oxidation processes serves to stabilize pH with the formation of bicarbonate ions.

A prediction of the fate of dyes will be most important because of the nature of the present project which is primarily concerned with the color pollution problem in textile dyehouse effluent. A great deal of difficulty is encountered in the prediction of a color of textile mill waste due to the ever-changing colors being requested by fashion. Some mills are predictable as to the color because of a tendency to stay predominantly with a single color. For example, a mill manufacturing work denims only would show a predominantly blue color owing to the fact that work denims are normally blue and are normally dyed with indigo colors. However, a mill which dyes and finishes floor covering material would show a range of color from the brightest red to the most brilliant green and the deepest blue. As the taste and requirements of fashion change, so do the colors which go into the makeup of fashionable floor covering. The predictions made will, therefore, reflect the quantity of dyes which find their ways into waste waters and streams and not with the specific colors resulting from their presence.

Problems encountered with dyes in streams are both esthetic and practical. The esthetic problems are caused by the reaction of people to a stream whose color is constantly changing with time. The farmer, whose livestock drink water from the stream, will very likely become greatly disturbed with a change in stream color. Since the outcome of drinking the colored water is unknown, the stream probably be restricted from the livestock. Some other practical problems which have been encountered have involved the lack of degradation of a particular dye in a stream so that it passed through a municipal water treatment plant without significant change (6). A yellow dye was specifically involved; its presence was not as obvious as some other colors would have been. A textile finishing plant using the treated water for rinsing after bleaching, discovered that the yarn, which should have been white, had a yellow cast which had obviously resulted from adsorption of the yellow dye. Although the concentration had been very low it was high enough to significantly discolor the yarn.

A study of the degradation of dyes in streams is forthcoming as part of this project (7). It is felt that if some indication is given of the total amount of dyes to be found in streams then future work can go into a more detailed study of those classes of dyes responsive to treatment and degradation, and those, unresponsive.

Predictions as to the fate of other chemical auxiliaries will be limited to basic reactions such as anionic-cationic reactions and changes in processing of some of these chemicals. A detergent which is the salt of a long chain fatty acid can be reacted with other detergents to form an insoluble precipitate which will settle out in streams. The biodegradability of these chemicals is not given due to the magnitude of the problem and also the lack of applicability of this type of research to the present project. An extensive list of textile chemical specilities is available which reports the biochemical oxygen demand (BOD) of these chemicals (8).

Some chemicals such as resins and fiber manufacturer finishes are very difficult to identify because of their indefinite and varied chemical structure. The resins are designed to be deposited on the fibers in processing while the manufacturer's finishes are placed on the synthetic fibers to aid in mechanical processing. This means that the resins can be chemically reacted with fibers so that the result of this reaction will be a modified fiber and some by-product, which may or may not be removable by standard water or waste water treatment methods. The manufacturer's finishes such as anti-static agents are applied when the fiber is made so that the fiber will process with less difficulty, and are designed to come off in the finishing process when the fiber is washed or scoured. The presence of these types of chemicals in waste waters and streams, while it is known to exist, will not be shown in the results given because of the nature of the problem involving an intelligent prediction of the quantity and fate of these types of chemicals.

A classification is given as miscellaneous chemicals which includes resins and finishes as described above. These chemicals are those which have not been classified as acids, bases, dyes, salts, or anionic, cationic and nonionic detergents. For this reason the quantity of anionic, cationic and nonionic detergents is given as a total figure with further breakdown.

The quantity of chemicals used per pound of fiber product is obtained by dividing the total production of the mills supplying information by the poundage of each specific chemical reported. This gives a constant which, when multiplied by a production figure for either an individual mill or the total production in an area, will give the predicted quantity of the chemical in question.

CHAPTER III

DISCUSSION OF RESULTS

The results given will be shown in two separate parts and then as an overall total. The first part shown will be the tufted textile industry of the Coosa River Basin. This segment of the total textile industry was selected since it constitutes the major industry in the basin. It has been shown that textile employment ranks as the highest in the fourteen county area and out of this 67.7 percent is tufted textile employment (9). For this reason it must be assumed, based also on the nature of the tufted textile industry, that it is the major contributor of waste to the streams in the area.

The second part of the results given will be a prediction of the textile industry in the state as a whole. This will not include the tufted textile industry in the state but the final overall total will cover all phases which contribute waste to Georgia streams.

Table 2 shows the overall totals predicted for the tufted textile industry in the Coosa River Basin. These figures assume that this area constitutes ninety percent of all tufted production in the state (10).

It was necessary to bring the figures down to monthly and weekly bases so that their significance would be more readily understood. This was just a matter of dividing the yearly total of pounds of fibers used by twelve for a monthly average which is then divided by four for a weekly basis. No further breakdown is given because of a lack of consistency

Table 2. Forecast of Dyes and Auxiliaries Discharged into Streams in Coosa River Basin

Pounds of fiber and yarn consumed by tufted textile industry in Basin (1965)	Water (lbs)	Acid (lbs)	Base (lbs)	Dyes (lbs)	Salts (lbs)	Anionic Agents (lbs)	Nonionic Agents (lbs)	Unidentified (lbs)	Miscellaneous (lbs)
	(add 000) except calculations of mg/1								
Year-523,187	72,513,718 (9,064,200 gals)	732	350	827	111366	2893	24637	11201	3484
Month-43,599	6,042,821 (755,352 gals)	61	29	69	9280	241	2053	933	290
Week-10,900	1,510,740 (188,842 gals)	15	7	17	2320	60	513	233	73
	698,715 1	6804g	3175g	7711g	10,523,52g	27216g	23269g	105689g	33113g
		9.7mg/1	4.5mg/1	11mg/1	1506 mg/1	38.9mg/1	333mg/1	151mg/1	47mg/1
						Total	2101mg/1		

among mills about how many days per week they operate.

Water Use

The figures for pounds of water used per pound of fiber processed give an indication of the magnitude of water use in this area. When converted to gallons they take on more significance because it is possible to compare this with figures for total water use in the textile industry of Georgia shown in Table 1.

Acids and Bases

Table 2 illustrates that almost twice as many gross pounds of acid is used as alkali in the basin. The questionnaires showed that the principal acid used was sulfuric (H_2SO_4) and the principal alkali was sodium hydroxide (NaOH). A gross poundage ratio of 2 to 1 acid to base for these will be approximately (49 pounds acid equivalent to 40 pounds base) chemically equivalent from which it follows that a neutral salt (sodium sulfate) will replace the acid and base discharged. As mentioned earlier it is not possible to predict pH from these figures due to the difference in types of reactions possible with different acids and bases. A straightforward acid-base reaction will give a salt but again as mentioned earlier the pH of salts can vary from strongly acidic to strongly basic. Some structures of typical acids used by the textile industry in the Coosa River Basin are:

Sulfuric Acid - $H_2So_4 \rightarrow H^+ + HS\bar{O}_4$

Hydrochloric Acid - $HCl \rightarrow H^+ + Cl^-$

Acetic Acid - $CH_3COOH \rightarrow CH_3COO^- + H$

Formic Acid - $HCOOH \rightarrow HCOO^- + H^+$

The typical bases used and their structures are:

Caustic Soda (Sodium Hydroxide) - $NaOH \rightarrow Na^{+} + OH^{-}$

Soda Ash - $Na_2CO_3 + H_2O \rightarrow 2Na^{+} + CO_3^{--} + HCO_3^{-}$

Alkali Phosphate:

$$NaH_2PO_4 \rightarrow Na^{+} + 2H^{+} + PO_4^{---}$$

$$Na_2HPO_4 \rightarrow 2Na^{+} + H^{+} + PO_4^{---}$$

$$Na_3PO_4 \rightarrow 3Na^{+} + PO_4^{---}$$

The effect of acids and bases on water quality of streams is twofold. First, the shock load of a strongly acidic or strongly basic effluent on a stream will have a greater adverse effect on all living matter in the stream than a steady acidic or basic discharge. This means that living material will not be found in or around the vicinity of a waste water outfall. While the two types of chemicals have a balancing effect after mixing, it is the initial load which determines final conditions. Secondly, recovery from extreme pH variations can occur rather rapidly, depending on the size of the receiving stream; the long term effect may or may not present practical difficulties. Dilution, absorption, and precipitation occur so that the pH of the stream approaches a stable level and the total concentration of ions declines.

Dyes

The most obvious factor describing a stream is the color of the stream. This makes the presence of dyes in the streams the major problem of this thesis. It can be seen in Figure 1 that seventeen thousand pounds of dye are discharged into streams per week. It is important to note that this is the amount of waste, not the total amount used. This is based on ninety percent exhaustion which was felt to be representative of most dye houses in the area. The figure for milligrams of dye per litre of waste waters is 11.0 for which a spectural transmission curve is shown in Figure 2. These dyes are varied in type and structure but a list of dyes representative of the types most widely used by the textile industry in the Coosa River Basin are shown by color index number in Table 3.

Table 3. Dyes Representative of the Types Most Widely Used by the Textile Industry in the Coosa River Basin

C.I. Acid Red 182
C.I. Acid Yellow 151
C.I. Basic Red 18
C.I. Basic Yellow 25
C.I. Basic Blue 21
C.I. Direct Blue 67
C.I. Direct Orange 34
C.I. Direct Red 87
C.I. Disperse Blue 3
C.I. Disperse Yellow 32
C.I. Vat Red 13
C.I. Vat Green 1

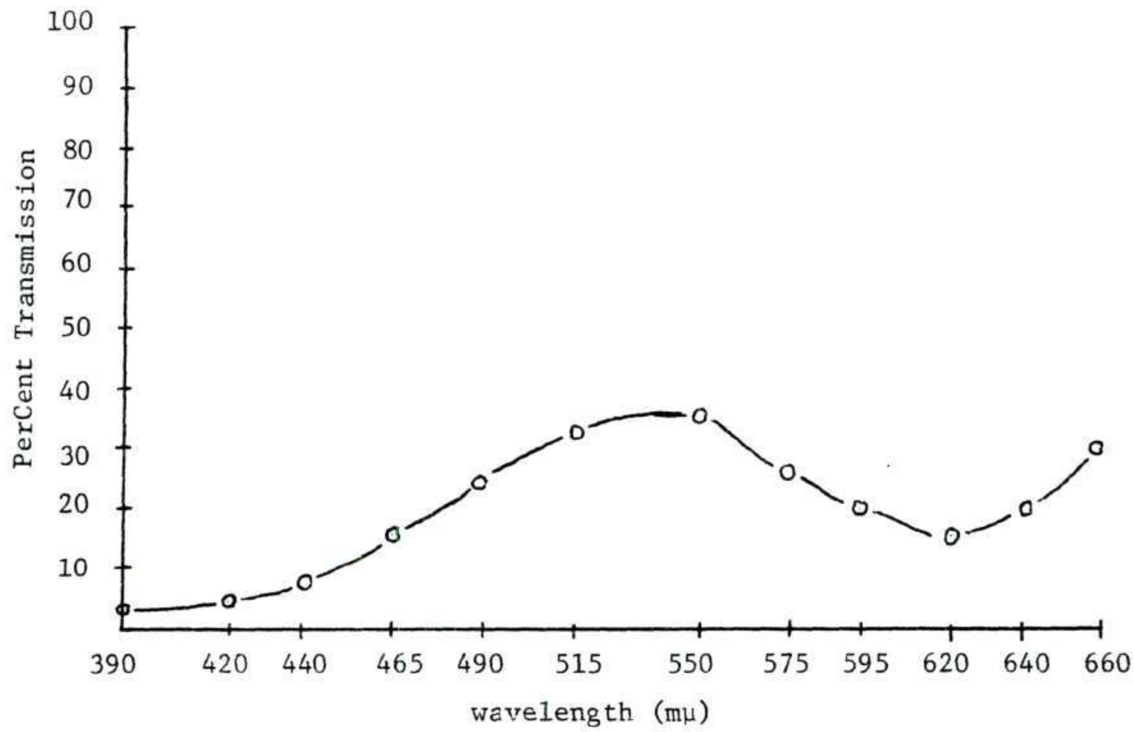

Figure 2. Spectral Curve for Laboratory Sample

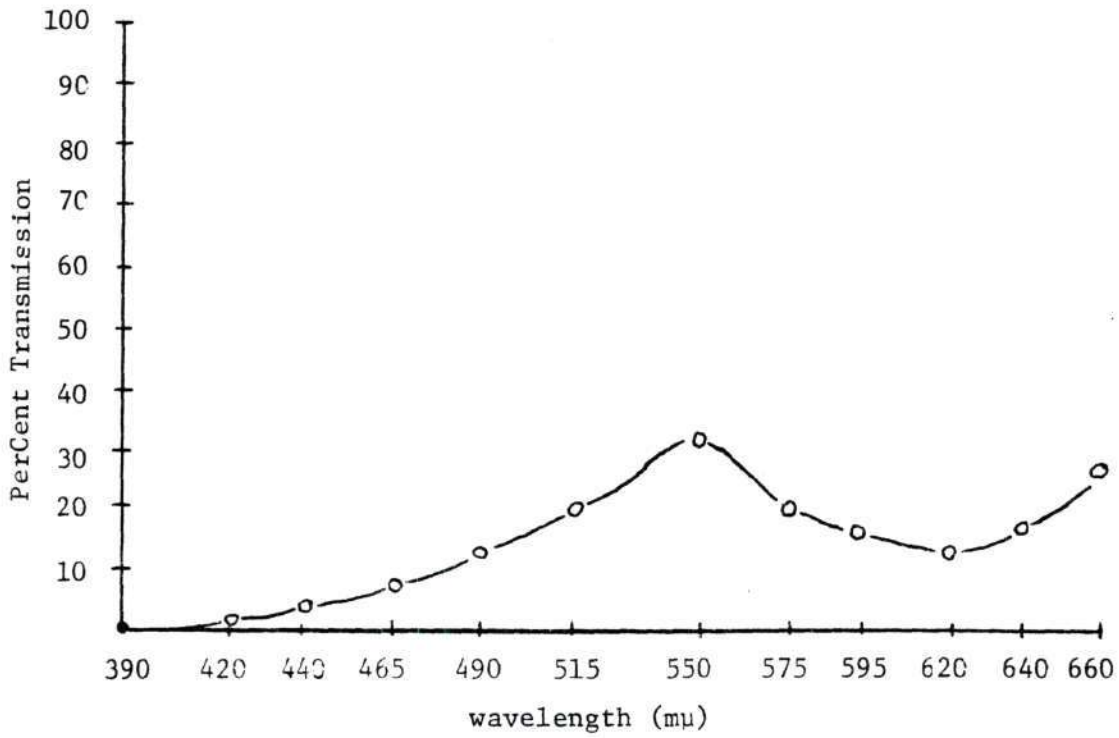

Figure 3. Spectral Curve for Stream Sample

The fate of these dyes is not predictable although some earlier work has sown the biochemical oxygen demand (BOD) of dyes (11). It is not the purpose of this research to predict the fate of these dyes but rather to predict the quantity which could be found in Georgia streams. When the results from the questionnaires were received and studied a sample was made up with the concentration based on dye used, exhaustion, and water used. The results of this are shown in Figure 2 as a spectral transmission curve. This was compared with a sample taken from a stream containing dye effluent. The curve for the stream sample is shown in Figure 3.

A comparison of the two curves shows good agreement and indicates that it is possible to get a paper study with good results when dealing with a subject such as dyes.

Anionic Dyeing and Finishing Agents

The chemicals in this class are generally described as anionic surfactants without regard to specific use. Here, as with cationic, nonionic and other chemicals, many chemicals were reported by proprietary names or trade names rather than by chemical type. Much work was necessary to identify them by their chemical type since this work was not intended to study use of the chemicals in various processes.

The largest group of anionic agents are softeners for use on natural or regenerated fibers. These softeners were originally manufactured from natural oils, fats, and waxes but recently many products have been derived from synthesized fatty alcohols, alkyl sulfates, and fatty anionic alkylolamides. The structure of sulfated fatty esters based on stearic acid is (12):

$$\begin{array}{l} \text{R-CH-COOH} \\ \quad\;| \\ \quad\;\text{OSO}_3\text{H} \end{array}$$

The fate of anionic detergents and softeners in waste waters has not been clearly established; it is known, however, that anionic auxiliaries will combine with available cations and precipitate.

Cationic Dyeing and Finishing Agents

The quantity of these chemicals used is so small that it is of no significance. The reason for the lack of use is primarily the fate of the chemicals in a bath. These compounds are very sensitive to anionic substances and will form sticky precipitates in their presence (13). This makes their popularity somewhat limited in textile finishing operations since most dyeing and finishing baths contain considerable quantities of various chemicals which do not create a favorable environment for these chemicals.

Nonionic Dyeing and Finishing Agents

Unlike anionic and cationic agents, these have the advantage of being compatible with many other textile finishing agents and therefore may be added to bleaching or dyeing liquors as well as to finishing baths and they are used for both natural and man-made fibers.

Here, as with anionic agents, most of these are classified as softeners but also act as antistatic agents and may be leveling agents as well. Most nonionic softeners are made by reacting various fatty acids and alcohols on their related fatty esters and amides to give polyoxyethylene derivatives. Recently emulsified polyethylene has become important for use with the newer resins and finishes. Typical structures of nonionic softeners are:

$$\text{Ethylene Oxide} - \overset{O}{\overset{/\;\backslash}{CH_2\text{-}CH_2}}$$

Oleic Acid based Product $CH_{17}H_{33}COOC_2H_4(C_2H_4O)x\text{-}2C_2H_4OH$

Stearyl Polyethylene ether - $C_{18}H_{37}O(CH_2CH_2O)_{30}$ H

Salts

Sodium chloride is the principal salt used. This is because of the amount of direct dyeing of cellulosic fibers where high concentrations of salt are used to render the fibers more electropositive and increase the adsorption of the dye anions. Reported data disclosed that sodium chloride accounted for ninety percent of all neutral salts used in textile wet-processing; the other salts were accordingly reported as sodium chloride. In solution sodium chloride dissociates into sodium and chloride ions. The concentration of chloride ions was forecast to be 1506 mg/l. which corresponded to analyses of streams containing both treated and untreated textile wet-processing waste (14).

Unidentifiable Chemicals

As mentioned earlier many chemicals were reported which were not identified as to anionic, cationic, nonionic and did not fall into any known classification. A majority of these chemicals are manufactured specifically for one use by a vendor. This means that the chemical is not used industry-wide and its effect on the total picture was ignored.

Miscellaneous

Chemicals which could not be classified under normal headings and did not alone constitute sufficient quantity to warrant a separate heading were placed in this class. Some examples of these are borax, ethylene glycol, sodium dithionite, and anti-foaming agents. The fate of these miscellaneous chemicals in waste waters and streams was not significant enough to warrant extensive study due to the quantities involved and the variation from mill to mill.

Total for Tufted Textile Industry in Basin

The total pounds of all chemicals including dyes, acids, bases and ausiliaries used by the textile industry in the Coosa River Basin is 3,238,000 per week. This is related to water use to give a relative dilution estimate or the number of pounds of chemicals per gallon of water. The number of gallons of water used per week is 188,842,500. Therefore, the quantity of chemicals to be found per gallon water is 0.017. This carried further can give a total milligrams per litre estimate for the area. This is shown in Table 2. The total of all chemicals shown as milligrams per litre is 2,101. This figure can be compared with totals found in the stream survey.

Future Indications

From the results given predictions are possible based on future production forecasts. The tufted textile industry expects production to be doubled by 1970 (15). This forecast does not mean that the industry will double in its present location. There is a trend to locate new floor covering mills outside the northwest Georgia area presently so heavily concentrated with this type operation (16). There will, however, be an increase in production in the area. As the poundage of goods increases, there will be a greater demand for water because of its underlying importance to textile wet-processing. This may lead to the re-use of water to a much greater extent than at present. Appendix A shows information concerning water use by the textile industry in the United States as a whole and in the Southeast.

The relative amount of chemicals to water will not increase a great deal, i.e., the concentration in waste waters. In fact, due to technological advances in processing a decrease in concentration may occur. The overall volume will increase, however, as Table 4 shows. The production shown is a ninety percent increase which is quite liberal but which will indicate to what extent the problem could grow without corrective measures.

Table 4. Forecast of Quantities of Chemicals to be Discharged into Streams of the Coosa River Basin by 1970*
(thousands of pounds per week)

Process Water	Acid	Base	Dyes	Anionic Agents	Nonionic Agents	Salts	Uniden-tified	Miscel-laneous
2,870,406	29	14	33	115	975	4408	443	138

*Based on 20,710,000 pounds of fiber processed weekly which represents a 90 percent increase in production for this area.

CHAPTER IV

CONCLUSIONS

1. Many chemicals used in textile processing serve the purpose of creating an environment for the interaction of fibers with other specific chemicals.

2. Quantities of selected textile chemicals present in streams may be accurately forecast from quantities actually used per pound of fiber processed.

3. Total textile processing chemicals present at selected points in the Coosa River Basin have been calculated to approximate 2000 mg/l (0.2%); neutral salts constitute 75% of this total; nonionic detergents account for 15% of the total; dyestuffs were estimated at 11.0 mg/l (0.001%); acids and bases were approximately stoichiometrically equivalent.

4. Although dyestuffs do not constitute the major chemical discharged, in terms of concentration, the magnitude and distribution is such that receiving streams may be highly colored at the point of effluent discharge at specific times.

CHAPTER V

RECOMMENDATIONS

It is recommended that further research be undertaken going into more detail on chemicals actually discharged into streams; the concentration of dye necessary to be visible in a stream should be determined. Also much work needs to be done on classification of textile auxiliaries and their ultimate fate after processing. This research should be carried out jointly by the textile industry, chemical suppliers, and educational institutions.

It is further recommended that information be made more readily available for research into problems which face the textile industry. Although much work is being done by the textile industry concerning water pollution, the problem is yet to be solved and only the help of the industry can lead to a total solution.

APPENDIX A

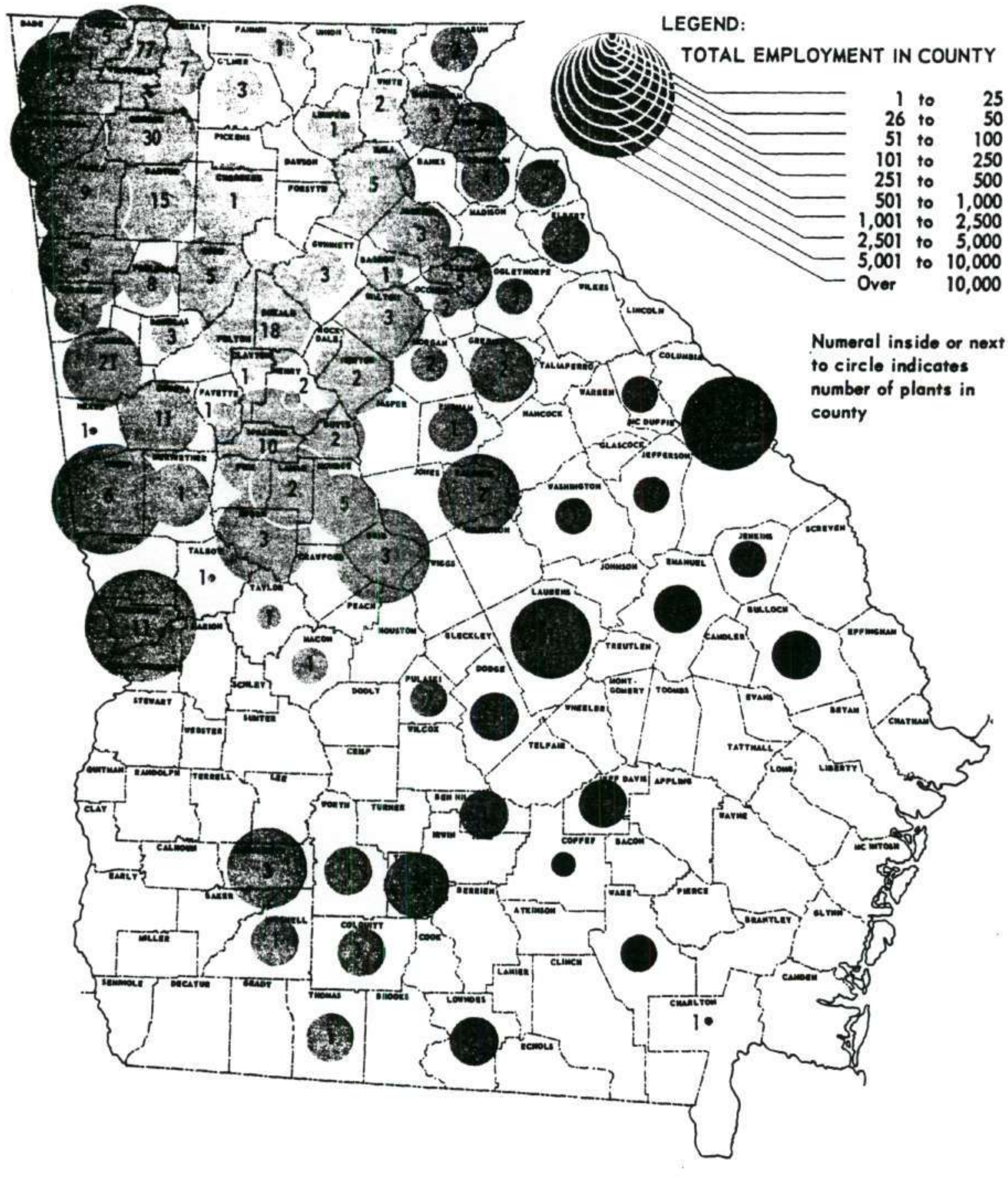

Figure 4. Textile Industry in Georgia
(Source: Georgia Manufacturing Atlas, Georgia Institute of Technology, 1965.)

Figure 5. Coosa River Basin in Northwest Georgia

Sample of Cover Letter

Georgia Institute of Technology
A. French Textile School
Atlanta, Georgia

Multicolor Fabrics, Inc.
Spectral Street
Dyetown, Georgia

Dear Sir:

Quality of water in Georgia streams available for domestic and industrial usage is of ever increasing public concern.

The quantity available is determined by natural phenomena and an increase with passage of time is unlikely. More effective usage of existing and potential supplies along with improved methods and techniques for preventing further declines in quality of the available supply is both desirable and essential. Agencies charged with the responsibility for controlling water quality may develop increasingly restrictive controls, particularly if the decline in quality continues.

Through the Water Resources Center and the A. French Textile School at Georgia Institute of Technology, a project has been undertaken to evaluate the contribution made by the textile industry in Georgia to changing quality or utility of the water in the streams with particular reference to color, and chemicals used in dyeing and finishing operations.

It is hoped that data may be obtained and correlated which will illustrate that action now being taken in waste control measures is effective in reducing the total contribution of the textile industry to the overall problem.

One approach toward a better and more precise definition of the problem is that of charting the quantity of water, chemicals and dyestuffs, consumed per pound of fiber yarn or fabric processed.

It is recognized that such figures will range widely for different products and manufacturing processes.

Cumulatively the data should provide an order of magnitude estimate of the maximum chemical and dyestuff content of streams since the rate of water flow in the streams at periods of low rainfall is known.

We sincerely hope that you will provide some of the factual data that will be needed in an attempt to better define the part played by your processing operations in the total waste control and pollution problem.

Sample of Cover Letter (page 2)

We have enclosed a form for reporting items of information that will be useful in completing the study. We would appreciate your returning the completed form to us in the enclosed envelope. All information is confidential and will merely form a part of a total picture. The total is however only the sum of the parts and we have no other way to arrive at the big picture.

You may omit your corporate name and location. Data may be provided in a form most suitable to you.

We have provided several choices for quantity or time units to be used. We can convert the units to a common basis. Indeed, this will be required in order to make the quantities additive and to provide a meaningful "sample" of total textile chemical dyestuff and fiber waste that may flow directly into the streams or indirectly through municipal or other treatment facilities.

Results of this study will be available in a formal report to the Water Resources Center.

Your assistance will be appreciated.

Sincerely,

A. French Textile School
Georgia Institute of Technology

Research Assistant
Mr. Larry G. Arnold

Encl.

Sample of Questionnaire 1

COMPANY NAME __________________

LOCATION __________________

____

****

WATER AND WASTE DISPOSAL:

1. Source of water supply:

   ( ) Municipal ( ) Stream ( ) Spring ( ) Other ________

2. Waste water discharged to:

   ( ) Municipal ( ) Pond ( ) Stream ( ) Other ________

	Hour	Day	Week	Month
3. Quantity water consumed ( ) gals. ( ) cf. ( ) Other	____	____	____	____

MATERIALS AND PROCESSING:

	Day	Week	Month
1. Average hours worked	____	____	____
2. Total pounds processed	____	____	____

3. Fiber distribution (% of total):

   ( ) Cotton ( ) Wool ( ) Acrylic ( ) Other

Sample of Questionnaire 1 (continued)

CHEMICALS USED:

	Day	Week	Month	Year
1. Acids: Mineral (sulfuric, etc.)				
Other (acetic, etc.)				
2. Bases: Caustic Soda				
Soda Ash				
Phosphates				
3. Detergents:				
4. Wetting Agents:				
5. Dyestuffs:				
6. Other Chemicals:				
____________				
____________				
____________				

Any additional information will be appreciated, for example, exhaustion of dyes, etc.

Sample of Questionnaire 2

COMPANY NAME ________________

LOCATION ________________

____

****

WATER AND WASTE DISPOSAL:

1. Source of water supply:

( ) Municipal ( ) Stream ( ) Spring ( ) Other ________

2. Waste water discharged to:

( ) Municipal ( ) Pond ( ) Stream ( ) Other ________

	Hour	Day	Week	Month
3. Quantity water consumed ( ) gals. ( ) cf. ( ) Other	____	___	____	_____

MATERIALS AND PROCESSING:

	Day	Week	Month
1. Average hours worked	____	____	_____
2. Total pounds processed	____	____	_____

3. Fiber distribution (% of total)

( ) Nylon ( ) Polypropylene ( ) Polyester

( ) Viscose ( ) Cotton ( ) Wool

( ) Acrylic ( ) Other

Sample of Questionnaire 2 (continued)

CHEMICALS USED:

Totals may be reported on daily, weekly, monthly, or yearly basis. The time period should be stated.

	Day	Week	Month	Year
1. Acids: Mineral (sulfuric, etc.)				
Other (acetic, etc.)				
2. Bases: Caustic Soda				
Soda Ash				
Phosphates				
3. Dyestuffs:				
4. Detergents, Wetting Agents, other chemicals either generic or trade name will be satisfactory. If records are on a yearly basis, totals for the year may be listed.				
________________				
________________				
________________				
________________				
________________				

Any additional information will be appreciation, for example, exhaustion of dyes, etc.

Sample of Questionnaire 3

COMPANY NAME ________________

LOCATION ________________

____

****

WATER AND WASTE DISPOSAL:

1. Source of water supply:

( ) Municipal ( ) Stream ( ) Spring ( ) Other ________

2. Waste water discharged to:

( ) Municipal ( ) Pond ( ) Stream ( ) Other ________

	Hour	Day	Week	Month
3. Quantity water consumed ( ) gals. ( ) cf. ( ) Other				

MATERIALS AND PROCESSING:

	Day	Week	Month
1. Average hours worked	___	___	___
2. Total pounds processed	___	___	___

3. Fiber Distribution (% of total)

( ) Nylon ( ) Polypropylene ( ) Polyester

( ) Viscose ( ) Cotton ( ) Wool

( ) Acrylic ( ) Other

Sample of Questionnaire 3 (continued)

CHEMICALS USED:

		Week	Month	Year
1. Acids:	Mineral - Sulfuric, etc.			
	Other			
2. Bases:	Caustic Soda			
	Soda Ash			
	Phosphates			
3. Dyes:				
4. Salts:				
5. Detergents, Wetting Agents, Other Chemicals: (Please give total poundage rather than trade names)				

Please include any figures available concerning % exhaustion.

APPENDIX B

Table 5. Water Use in Manufacture of Textile Mill Products in United States*

Year	Water Intake			Gross Water Used	Water Discharged		All Employees[1] (add 000)
	Total	Fresh	Brackish		Total	Treated Prior to Discharge	
1954	184	181	3	211	147	13	454
1959	135	135	1	182	120	17	378
1964	148	146	1	311	135	35	353

[1]Includes employees in establishments consuming 20 million gallons or more water.

*In billion gallons, except employees.

Source: Bureau of the Census, Census of Manufactures.

Table 6. Water Intake by Purpose, Gross Water Used and Water Discharged, 1964, for Manufacture of Textile Mill Products in United States*

Industry Group	Water Intake by Purpose: All Purposes: Total (billion gallons)	All Purposes: Treated prior to use	Process	Cooling, Condensing: Steam Electric Generation	Cooling, Condensing: Other	Boiler Feed, Sanitary and Other	Establishments recirculating or reusing water (number)	Gross Water Used[1]	Total Water Discharged
Textile Mill Products	148	90	106	9	15	17	331	311	135
Weave Mills, Cotton	27	19	16	2	3	5	84	87	23
Weave Mills, Synthetics	10	5	7	(2)	1	2	52	27	9
Wool, Weave & Finishing	19	11	16	1	(2)	2	28	20	18
Knitting Mills	7	4	5	(2)	1	1	30	54	6
Finishing, except Wool	59	40	48	3	2	5	55	67	54
Floor Covering Mills	7	5	4	1	(2)	1	20	23	7
Yarn, Thread Mills	7	5	4	1	1	1	34	13	6
Misc. Textile Goods	12	3	4	(2)	7	1	26	21	12

[1]Includes recirculation and reuse.

*All figures in billion gallons except number establishments.

Source: Bureau of the Census, Census of Manufactures.

Table 7. Water Intake by Purpose, Gross Water Used, and Water Discharged, 1964, for Textile Mill Products in Southeast*

Industry Group	Water Intake by Purpose: All Purposes: Total	All Purposes: Treated prior to use	Process	Cooling, Condensing: Steam Electric Generation	Cooling, Condensing: Other	Boiler Feed, Sanitary and Other	Establishments recirculating or reusing water (number)	Gross Water Used[1]	Total Water Dis-charged
Textile Mill Products	84	62	62	4	7	12	216	177	75
Weave Mills, Cotton	24	17	14	2	3	5	78	84	21
Weave Mills, Synthetics	8	4	5	(2)	1	2	43	24	6
Wool Weaving, Finishing	7	7	6	(2)	(2)	1	10	8	7
Cotton, Finishing	25	20	21	1	1	1	19	30	22
Synthetics Finishing	7	5	5	-	(2)	2	8	9	6
Finishing Other	2	1	2	(2)	(2)	(2)	3	2	2
Finishing Tufted Carpets and Rugs	3	2	3	-	(2)	(2)	9	4	3
Yarn and Thread Mills	4	4	3	-	(2)	2	22	8	4

[1] Includes recirculation and reuse.

*All figures in billion gallons except number establishments.

Source: Bureau of the Census, Census of Manufactures.

Table 8. General Statistics for Counties Wholly Contained in Coosa River Basin (1963)

County	Establishments Total (number)	With 20 or more employees	All Employees Total (number)	All Employees Payroll ($1,000)	Production Workers Total (number)	Production Workers Man-hours (1,000)	Wages ($1,000)	Value Added by Mfr. (adj.) ($1,000)	Capital Expenditures New ($1,000)
Bartow	57	27	3,273	11,322	2,896	5,327	8,883	24,523	1,656
Chatooga	16	8	4,284	15,603	3,893	7,978	13,516	34,554	2,653
Cherokee	49	8	2,344	6,674	2,132	4,049	5,503	9,534	724
Dawson	4	1	210	101	206	(D)	(D)	(D)	(D)
Floyd	97	46	10,116	47,473	8,401	17,197	35,679	109,644	5,305
Gilmer	27	6	930	2,588	876	1,646	2,248	4,082	142
Gordon	57	24	13,210	11,166	2,873	6,051	8,998	35,988	1,188
Murray	25	4	532	1,631	495	1,020	1,399	2,848	231
Paulding	28	4	450	1,167	410	753	1,013	1,902	123
Pickens	24	5	971	3,338	880	1,784	3,019	4,846	545
Polk	38	16	3,562	14,110	3,070	6,045	11,067	29,050	1,803
Whitfield	186	92	11,071	41,914	9,364	18,873	30,883	99,756	4,060

Source: Bureau of the Census, Census of Manufactures.

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